Single Digitally Controlled Potentiometer (XDCP™)

The Intersil X9314 is a solid state nonvolatile potentiometer and is ideal for digitally controlled resistance trimming.

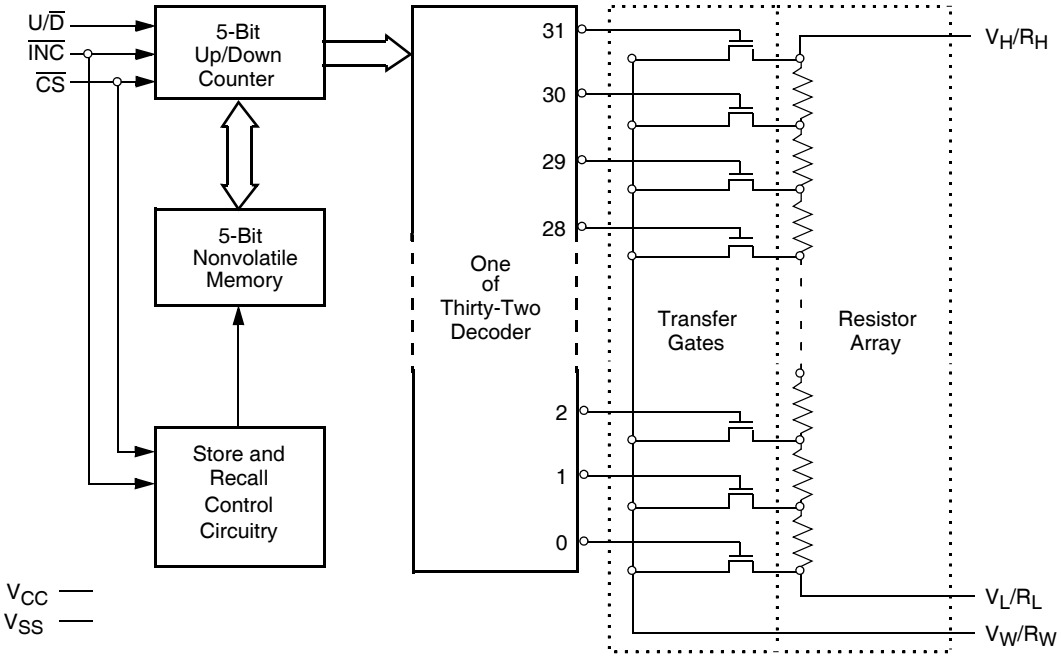
The X9314 is a resistor array composed of 31 resistive elements. Between each element and at either end are tap points accessible to the wiper element. The position of the wiper element is controlled by the $\overline{CS}$, U/$\overline{D}$, and $\overline{INC}$ inputs. The position of the wiper can be stored in nonvolatile memory and then be recalled upon a subsequent power-up operation.

The XDCP can be used as a three-terminal potentiometer or as a two-terminal variable resistor in a wide variety of applications including control, parameter adjustments, and signal processing.

Features

- Solid State Potentiometer
- 32 Taps
- 10kΩ End to End Resistance
- Three-Wire Up/Down Serial Interface
- Wiper Resistance, 40Ω Typical
- Nonvolatile Storage and Recall on Power-up of Wiper Position Standby Current < 500µA Max (Total Package)
- V_{CC} = 3V to 5.5V Operation
- 100 Year Data Retention
- Offered in 8 Ld MSOP, SOIC and PDIP Packages
- Pb-Free Plus Anneal Available (RoHS Compliant)

Block Diagram



Ordering Information

PART NUMBER	PART MARKING	V_{CC} RANGE (V)	R_{TOTAL} (kΩ)	TEMP RANGE (°C)	PACKAGE	PKG. DWG. #
X9314WMI*	14WI	5 ±10%	10	-40 to +85	8 Ld MSOP	M8.118
X9314WP	X9314WP			0 to +70	8 Ld PDIP	MDP0031
X9314WPI	X9314WP I			-40 to +85	8 Ld PDIP	MDP0031
X9314WS*	X9314W			0 to +70	8 Ld SOIC	M8.15
X9314WSI*	X9314W I			-40 to +85	8 Ld SOIC	M8.15
X9314WSIZ (Note)	X9314W ZI			-40 to +85	8 Ld SOIC (Pb-free)	M8.15
X9314WSZ* (Note)	X9314W Z			0 to +70	8 Ld SOIC (Pb-free)	M8.15
X9314WMI-3*	AAY	3 to 5.5		-40 to +85	8 Ld MSOP	M8.118
X9314WMIZ-3* (Note)	DEX			-40 to +85	8 Ld MSOP (Pb-free)	M8.118
X9314WS-3*	X9314W D			0 to +70	8 Ld SOIC	M8.15
X9314WSZ-3* (Note)	X9314W ZD			0 to +70	8 Ld SOIC (Pb-free)	M8.15

*Add "T1" suffix for tape and reel.

NOTE: Intersil Pb-free plus anneal products employ special Pb-free material sets; molding compounds/die attach materials and 100% matte tin plate termination finish, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.

Pin Descriptions

V_H/R_H and V_L/R_L

The high (V_H/R_H) and low (V_L/R_L) terminals of the X9314 are equivalent to the fixed terminals of a mechanical potentiometer. The minimum voltage is –5V and the maximum is +5V. It should be noted that the terminology of V_L/R_L and V_H/R_H references the relative position of the terminal in relation to wiper movement direction selected by the U/$\overline{D}$ input and not the voltage potential on the terminal.

V_W/R_W

V_W/R_W is the wiper terminal, equivalent to the movable terminal of a mechanical potentiometer. The position of the wiper within the array is determined by the control inputs. The wiper terminal series resistance is typically 40Ω.

Up/Down (U/$\overline{D}$)

The U/$\overline{D}$ input controls the direction of the wiper movement and whether the counter is incremented or decremented.

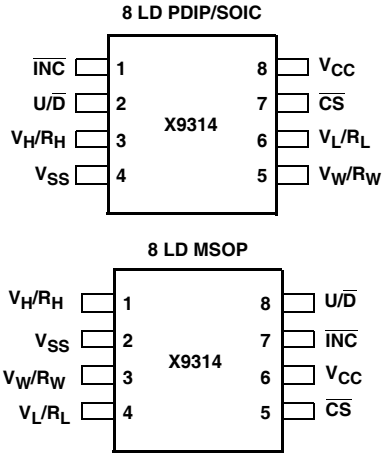
Increment ($\overline{INC}$)

The $\overline{INC}$ input is negative-edge triggered. Toggling $\overline{INC}$ will move the wiper and either increment or decrement the counter in the direction indicated by the logic level on the U/$\overline{D}$ input.

Chip Select ($\overline{CS}$)

The device is selected when the $\overline{CS}$ input is LOW. The current counter value is stored in nonvolatile memory when $\overline{CS}$ is returned HIGH while the $\overline{INC}$ input is also HIGH. After the store operation is complete the X9314 will be placed in the low power standby mode until the device is selected once again.

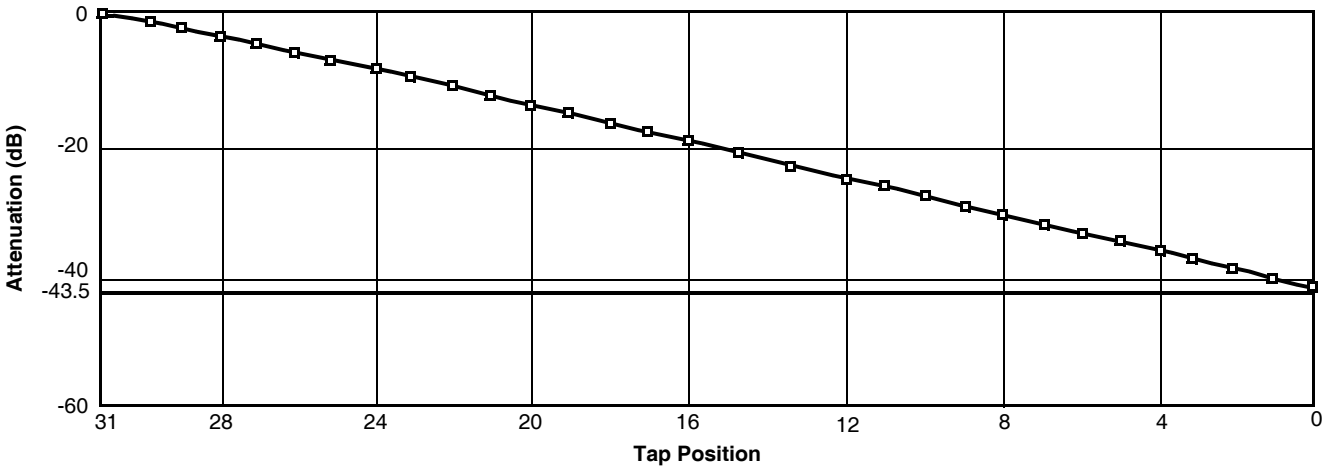
Pin Configuration



Pin Names

SYMBOL	DESCRIPTION
V_H/R_H	High Terminal
V_W/R_W	Wiper Terminal
V_L/R_L	Low Terminal
V_{SS}	Ground
V_{CC}	Supply Voltage
U/$\overline{D}$	Up/Down Input
INC	Increment Input
CS	Chip Select Input

Typical Attenuation Characteristics (dB)



Principles of Operation

There are three sections of the X9314: the input control, counter and decode section; the nonvolatile memory; and the resistor array. The input control section operates just like an up/down counter. The output of this counter is decoded to turn on a single electronic switch connecting a point on the resistor array to the wiper output. Under the proper conditions the contents of the counter can be stored in nonvolatile memory and retained for future use. The resistor array is comprised of 31 individual resistors connected in series. At either end of the array and between each resistor is an electronic switch that transfers the potential at that point to the wiper.

The $\overline{INC}$, U/$\overline{D}$ and $\overline{CS}$ inputs control the movement of the wiper along the resistor array. With $\overline{CS}$ set LOW the X9314 is selected and enabled to respond to the

U/$\overline{D}$ and $\overline{INC}$ inputs. HIGH to LOW transitions on $\overline{INC}$ will increment or decrement (depending on the state of the U/$\overline{D}$ input) a five bit counter. The output of this counter is decoded to select one of thirty-two wiper positions along the resistive array.

The wiper, when at either fixed terminal, acts like its mechanical equivalent and does not move beyond the last position. That is, the counter does not wrap around when clocked to either extreme.

The value of the counter is stored in nonvolatile memory whenever $\overline{CS}$ transistions HIGH while the $\overline{INC}$ input is also HIGH.

When the X9314 is powered-down, the last counter position stored will be maintained in the nonvolatile memory. When power is restored, the contents of the memory are recalled and the counter is reset to the value last stored.

Operation Notes

The system may select the X9314, move the wiper and deselect the device without having to store the latest wiper position in nonvolatile memory. The wiper

movement is performed as described above; once the new position is reached, the system would keep the $\overline{INC}$ LOW while taking $\overline{CS}$ HIGH. The new wiper position would be maintained until changed by the system or until a power-up/down cycle recalled the previously stored data.

This would allow the system to always power-up to a preset value stored in nonvolatile memory; then during system operation minor adjustments could be made. The adjustments might be based on user preference, system parameter changes due to temperature drift, etc.

The state of U/$\overline{D}$ may be changed while $\overline{CS}$ remains LOW. This allows the host system to enable the X9314 and then move the wiper up and down until the proper trim is attained.

t_{IW}/R_{TOTAL}

The electronic switches on the X9314 operate in a “make before break” mode when the wiper changes tap positions. If the wiper is moved several positions multiple taps are connected to the wiper for t_{IW} ($\overline{INC}$ to V_W change). The R_{TOTAL} value for the device can temporarily be reduced by a significant amount if the wiper is moved several positions.

Power-up and Down Requirement

The are no restrictions on the sequencing of V_{CC} and the voltages applied to the potentiometer pins during power-up or power-down conditions. During power-up, the data sheet parameters for the DCP do not fully apply until 1 millisecond after V_{CC} reaches its final value. The V_{CC} ramp rate spec is always in effect.

Absolute Maximum Ratings

Temperature under bias . . . . . -65°C to +135°C
Storage temperature . . . . . -65°C to +150°C
Voltage on $\overline{CS}$, $\overline{INC}$, U/$\overline{D}$, and
V_{CC} with respect to V_{SS} . . . . . -1V to +7V
Voltage on V_H/R_H and V_L/R_L referenced
to V_{SS} . . . . . -8V to +8V
$\Delta V = |V_H/R_H - V_L/R_L|$ 10V
Lead temperature (soldering 10s) . . . . . +300°C
Wiper current . . . . . ±1mA
I_W (10s) . . . . . ±8.8mA

Recommended Operating Conditions

Temperature (Commercial) . . . . . 0°C to +70°C
Temperature (Industrial) . . . . . -40°C to +85°C
Supply Voltage (V_{CC}) Limits
X9314 . . . . . 5V ± 10%
X9314-2.7 . . . . . 3V to 5.5V

CAUTION: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only; the functional operation of the device (at these or any other conditions above those listed in the operational sections of this specification) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Potentiometer Characteristics (Over recommended operating conditions unless otherwise stated.)

SYMBOL	PARAMETER	TEST CONDITIONS/NOTES	LIMITS			
			MIN	TYP	MAX	UNITS
R_{TOTAL}	End to End Resistance Tolerance				±20	%
	V_H/R_H Terminal Voltage		-5		+5	V
$V_{VL/RL}$	V_L/R_L Terminal Voltage		-5		+5	V
	Power Rating	at +25°C			10	mW
R_W	Wiper Resistance	I_W = ±1mA, V_{CC} = 5V		40	100	Ω
I_W	Wiper Current				±4.4	mA
	Noise	Ref: 1kHz		-120		dBV
	Relative variation. Error in step size between taps.	log ($R_{W(n)}$) - log $R_{W(n - 1)}$)	0.07-0.003		0.07 + 0.003	
	R_{TOTAL} Temperature Coefficient	for -40°C to +85°C		±600		ppm/°C
	Ratiometric Temperature Coefficient				±20	ppm/°C
$C_H/C_L/C_W$	Potentiometer Capacitance	See Circuit #3		10/10/25	pF	

NOTE:

1. This parameter is periodically sampled and not 100% tested.

DC Electrical Specifications (Over recommended operating conditions unless otherwise specified.)

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNITS
			MIN	TYP(2)	MAX	
I_{CC}	V_{CC} Active Current	$\overline{CS}$ = V_{IL}, U/$\overline{D}$ = V_{IL} or V_{IH} and $\overline{INC}$ = 0.4V/2.4V @ max. t_{CYC}		1	3	mA
I_{SB}	Standby Supply Current	$\overline{CS}$ = V_{CC} - 0.3V, U/$\overline{D}$ and $\overline{INC}$ = V_{SS} or V_{CC} - 0.3V			500	µA
I_{LI}	$\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input Leakage Current	V_{IN} = V_{SS} to V_{CC}			±10	µA
V_{IH}	$\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input HIGH Voltage		2		V_{CC} + 1	V
V_{IL}	$\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input LOW Voltage		-1		0.8	V
C_{IN}(3)	$\overline{CS}$, $\overline{INC}$, U/$\overline{D}$ Input Capacitance	V_{CC} = 5V, V_{IN} = V_{SS}, T_A = +25°C, f = 1MHz			10	pF

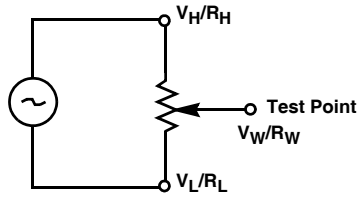
Standard Parts

PART NUMBER	MAXIMUM RESISTANCE	WIPER INCREMENTS	MINIMUM RESISTANCE
X9314W	10kΩ	Log Taper	40Ω

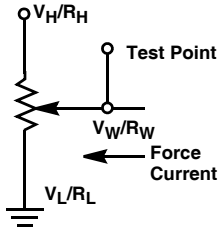
NOTES:

2. Typical values are for T_A = +25°C and nominal supply voltage.
3. This parameter is periodically sampled and not 100% tested.

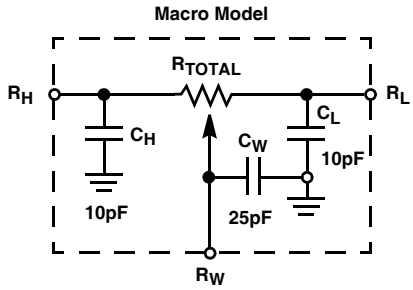
Test Circuit #1



Test Circuit #2



Circuit #3 SPICE Macromodel



A.C. Conditions of Test

INPUT PULSE LEVELS	0V to 3V
Input rise and fall times	10ns
Input reference levels	1.5V

Mode Selection

$\overline{CS}$	$\overline{INC}$	U/$\overline{D}$	MODE
L	↓	H	Wiper up
L	↓	L	Wiper down
↑	H	X	Store wiper position
H	X	X	Standby
↑	L	X	No store, return to standby

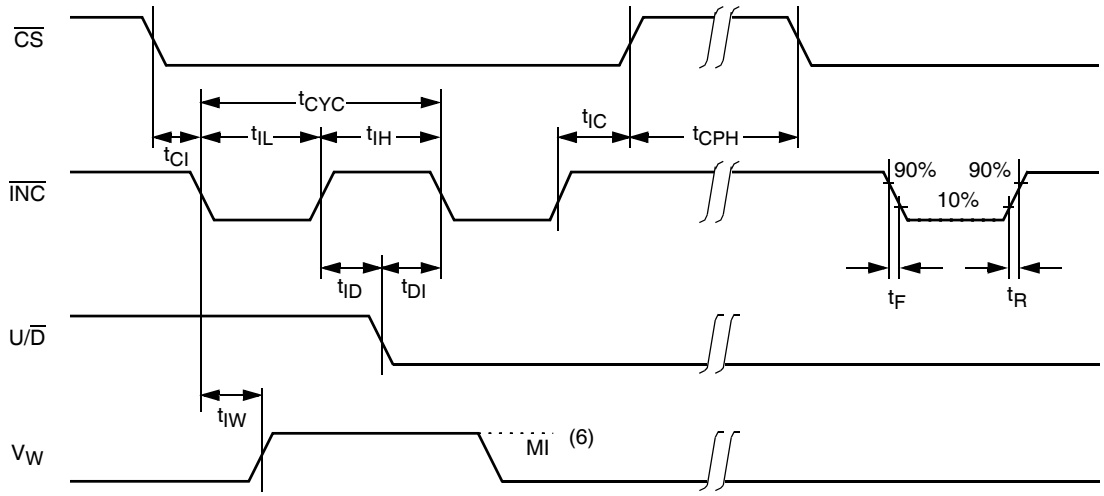
SYMBOL TABLE

WAVEFORM	INPUTS	OUTPUTS
	Must be steady	Will be steady
	May change from Low to High	Will change from Low to High
	May change from High to Low	Will change from High to Low
	Don't Care: Changes Allowed	Changing: State Not Known
	N/A	Center Line is High Impedance

AC Electrical Specifications (Over recommended operating conditions unless otherwise specified)

SYMBOL	PARAMETER	LIMITS			UNITS
		MIN	TYP(4)	MAX	
t_{CI}	$\overline{CS}$ to $\overline{INC}$ Setup	100			ns
t_{ID}	$\overline{INC}$ HIGH to U/$\overline{D}$ Change	100			ns
t_{DI}	U/$\overline{D}$ to $\overline{INC}$ Setup	2.9			µs
t_{IL}	$\overline{INC}$ LOW Period	1			µs
t_{IH}	$\overline{INC}$ HIGH Period	1			µs
t_{IC}	$\overline{INC}$ Inactive to $\overline{CS}$ Inactive	1			µs
t_{CPH}	$\overline{CS}$ Deselect Time	20			ms
t_{IW}	$\overline{INC}$ to V_W Change		100	500	µs
t_{CYC}	$\overline{INC}$ Cycle Time	4			µs
t_R, t_F(5)	$\overline{INC}$ Input Rise and Fall Time			500	µs
t_{PU}(5)	Power-up to Wiper Stable			500	µs
t_R V_{CC}	V_{CC} Power-up Rate	0.2		50	mV/µs

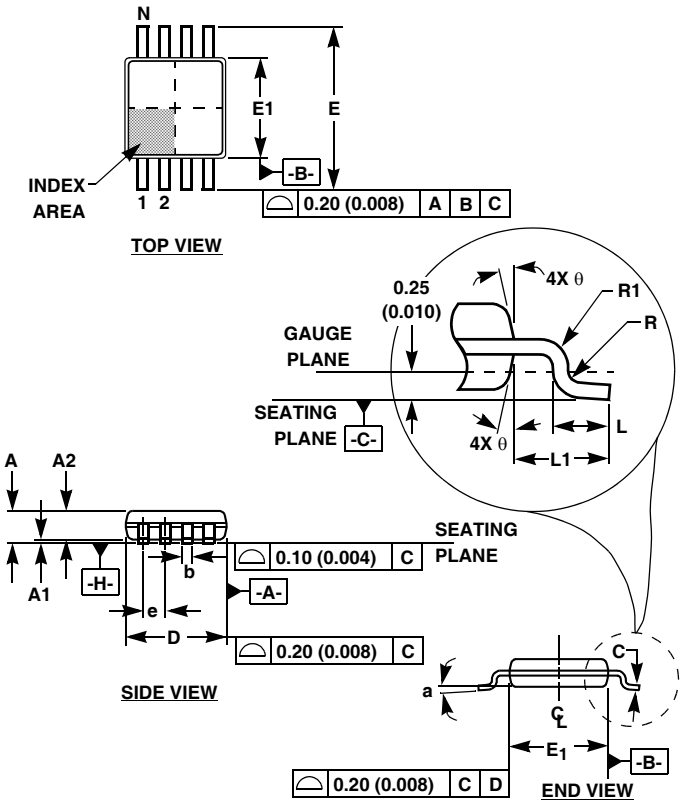
A.C. Timing



NOTES:

4. Typical values are for T_A = +25°C and nominal supply voltage.
5. This parameter is periodically sampled and not 100% tested.
6. MI in the A.C. timing diagram refers to the minimum incremental change in the V_W output due to a change in the wiper position.

Mini Small Outline Plastic Packages (MSOP)



NOTES:

1. These package dimensions are within allowable dimensions of JEDEC MO-187BA.
2. Dimensioning and tolerancing per ANSI Y14.5M-1994.
3. Dimension “D” does not include mold flash, protrusions or gate burrs and are measured at Datum Plane. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension “E1” does not include interlead flash or protrusions and are measured at Datum Plane. [- H -] Interlead flash and protrusions shall not exceed 0.15mm (0.006 inch) per side.
5. Formed leads shall be planar with respect to one another within 0.10mm (0.004) at seating Plane.
6. “L” is the length of terminal for soldering to a substrate.
7. “N” is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. Dimension “b” does not include dambar protrusion. Allowable dambar protrusion shall be 0.08mm (0.003 inch) total in excess of “b” dimension at maximum material condition. Minimum space between protrusion and adjacent lead is 0.07mm (0.0027 inch).
10. Datums [-A -] and [- B -] to be determined at Datum plane [- H -].
11. Controlling dimension: MILLIMETER. Converted inch dimensions are for reference only.

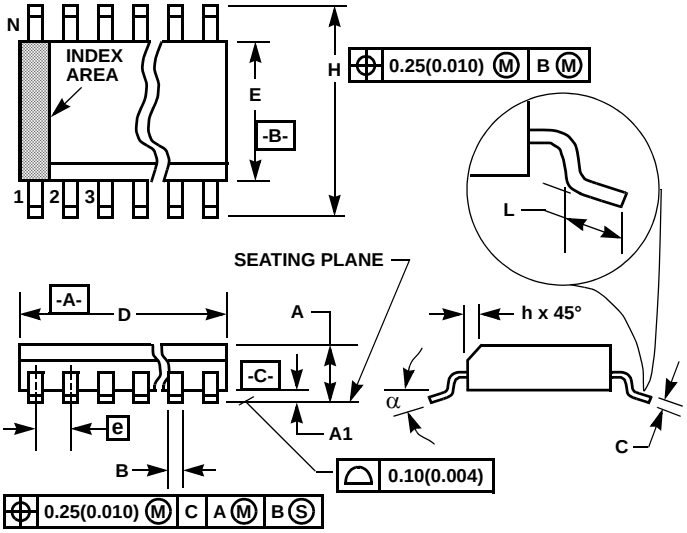
M8.118 (JEDEC MO-187AA)

8 LEAD MINI SMALL OUTLINE PLASTIC PACKAGE

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.037	0.043	0.94	1.10	-
A1	0.002	0.006	0.05	0.15	-
A2	0.030	0.037	0.75	0.95	-
b	0.010	0.014	0.25	0.36	9
c	0.004	0.008	0.09	0.20	-
D	0.116	0.120	2.95	3.05	3
E1	0.116	0.120	2.95	3.05	4
e	0.026 BSC		0.65 BSC		-
E	0.187	0.199	4.75	5.05	-
L	0.016	0.028	0.40	0.70	6
L1	0.037 REF		0.95 REF		-
N	8		8		7
R	0.003	-	0.07	-	-
R1	0.003	-	0.07	-	-
0	5^o	15^o	5^o	15^o	-
α	0^o	6^o	0^o	6^o	-

Rev. 2 01/03

Small Outline Plastic Packages (SOIC)



NOTES:

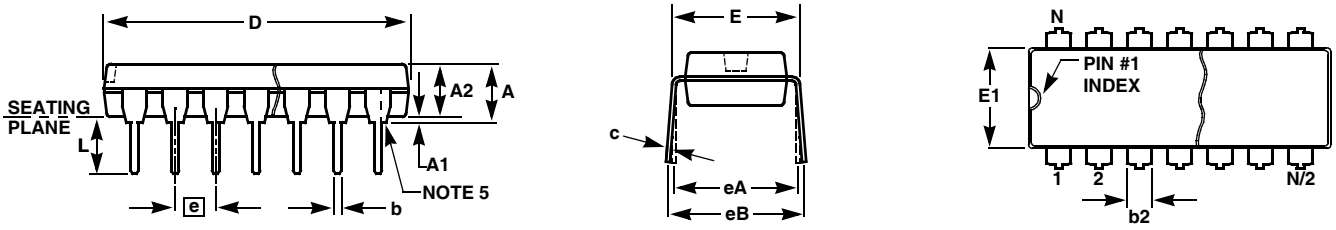
1. Symbols are defined in the “MO Series Symbol List” in Section 2.2 of Publication Number 95.
2. Dimensioning and tolerancing per ANSI Y14.5M-1982.
3. Dimension “D” does not include mold flash, protrusions or gate burrs. Mold flash, protrusion and gate burrs shall not exceed 0.15mm (0.006 inch) per side.
4. Dimension “E” does not include interlead flash or protrusions. Interlead flash and protrusions shall not exceed 0.25mm (0.010 inch) per side.
5. The chamfer on the body is optional. If it is not present, a visual index feature must be located within the crosshatched area.
6. “L” is the length of terminal for soldering to a substrate.
7. “N” is the number of terminal positions.
8. Terminal numbers are shown for reference only.
9. The lead width “B”, as measured 0.36mm (0.014 inch) or greater above the seating plane, shall not exceed a maximum value of 0.61mm (0.024 inch).
10. Controlling dimension: MILLIMETER. Converted inch dimensions are not necessarily exact.

M8.15 (JEDEC MS-012-AA ISSUE C)
8 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.0532	0.0688	1.35	1.75	-
A1	0.0040	0.0098	0.10	0.25	-
B	0.013	0.020	0.33	0.51	9
C	0.0075	0.0098	0.19	0.25	-
D	0.1890	0.1968	4.80	5.00	3
E	0.1497	0.1574	3.80	4.00	4
e	0.050 BSC		1.27 BSC		-
H	0.2284	0.2440	5.80	6.20	-
h	0.0099	0.0196	0.25	0.50	5
L	0.016	0.050	0.40	1.27	6
N	8		8		7
α	0°	8°	0°	8°	-

Rev. 1 6/05

Plastic Dual-In-Line Packages (PDIP)



MDP0031

PLASTIC DUAL-IN-LINE PACKAGE

SYMBOL	PDIP8	PDIP14	PDIP16	PDIP18	PDIP20	TOLERANCE	NOTES
A	0.210	0.210	0.210	0.210	0.210	MAX	
A1	0.015	0.015	0.015	0.015	0.015	MIN	
A2	0.130	0.130	0.130	0.130	0.130	±0.005	
b	0.018	0.018	0.018	0.018	0.018	±0.002	
b2	0.060	0.060	0.060	0.060	0.060	+0.010/-0.015	
c	0.010	0.010	0.010	0.010	0.010	+0.004/-0.002	
D	0.375	0.750	0.750	0.890	1.020	±0.010	1
E	0.310	0.310	0.310	0.310	0.310	+0.015/-0.010	
E1	0.250	0.250	0.250	0.250	0.250	±0.005	2
e	0.100	0.100	0.100	0.100	0.100	Basic	
eA	0.300	0.300	0.300	0.300	0.300	Basic	
eB	0.345	0.345	0.345	0.345	0.345	±0.025	
L	0.125	0.125	0.125	0.125	0.125	±0.010	
N	8	14	16	18	20	Reference	

Rev. B 2/99

NOTES:

1. Plastic or metal protrusions of 0.010” maximum per side are not included.
2. Plastic interlead protrusions of 0.010” maximum per side are not included.
3. Dimensions E and eA are measured with the leads constrained perpendicular to the seating plane.
4. Dimension eB is measured with the lead tips unconstrained.
5. 8 and 16 lead packages have half end-leads as shown.